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Detection of Acetone Gases Non-Invasive from Diabetic Patient Based on Ages and Gender Factor using Laser Photoacoustics Spectroscopy (LPAS)

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Abstract
Has developed a method of laser photoacoustic spectroscopy (LPAS) to measure the concentration of various types of gas tracing to the ppb level. This methods used to detect acetone gas from human breath of diabetic patient based on age and gender. Laser photoacoustic spectrometer operated at maximum laser power of 4,5 W and has a lower limit of detection (BDT) of (2,3 ± 0,2) ppb. The concentration of acetone gas on average for 30 patients with diabetes mellitus are at 624 ppb, whereas the concentration of acetone gas averaged 30 healthy volunteers is as high as 85 ppb. The correlation between the concentration of acetone to gender is not significant. Acetone gas concentration average of 14 male patients amounted to 584 ppb with a correlation of R^2 = 0,221 and 16 female patients amounted to 660 ppb with a correlation value of R^2 = 0,016 while the correlation of the concentration of acetone on the patient's age is significant in the amount of R^2 = 0,7094. For healthy volunteers, almost no correlation between the concentration of acetone gas to the age or gender of healthy volunteers. If age increases, the concentration of acetone in the body will increase.
Keywords: Laser Photoacoustic Spectroscopy (LPAS), acetone gas, diabetes mellitus

1. Introduction

One type of dangerous diseases with high population levels in Indonesia is diabetes mellitus. Has predicted that there will be an increase of more than 12 million patients in 2025 (Tjokroprawiro, 2002). Diabetes mellitus is a disease arising from elevated levels of glucose in the blood caused by deficiency of insulin or the body's decreased ability to use insulin. People with diabetes have high glucose levels in the blood and causes the formation of acetone. Acetone is detected through the levels in the liver and lungs so it can be detected through breath of humans (Alan and Hei Sook Sul, 2000).

Method of examination has been done is through a blood test (invasive) and could pose risks to the patient. It required an examination technique with high sensitivity to identify and determine the concentration of various types of gas tracing as a biological marker of a particular disease that is non-invasive and does not have a big risk to the patient. The examination techniques such as human breath gas analysis .

These last few years, has developed a method of laser photoacoustic spectroscopy (LPAS) to measure the concentration of various types of gas tracing to the ppb level. LPAS methods have the potential to revolutionize the diagnosis of invasive manner and can monitor a variety of metabolism in the human body as a non-invasive and point of care with a fast response time (Cernat, 2010). The working principle of laser photoacoustic spectrometer is to change the phase of radiation waves into waves have a certain frequency that can be detected photoacoustic and transferred into the gas levels.

In previous studies by Mitrayana et al (2008), LPAS methods used for early detection of certain diseases through the analysis of three types of tracing gas is ethylene, ammonia and acetone by breathing human. With the same investigation methods, this study is devoted to detecting acetone gas as a biological marker of diabetes mellitus. Sampling in the form of a breath of 30 patients with diabetes mellitus aged > 40 years and 30 healthy volunteer aged < 40 years as a control. Then analyzed the influence of age and gender of the gas concentration of acetone obtained.

2. Characteristics of Laser Photoacoustic Spectrometers Intracavity

CO_2 laser power optimation to maximize the performance of laser photoacoustic spectrometer. Then measure the background signal and noise, calibration of the standard acetone gas (C_3H_6O) to determine the acetone gas on the laser line 10P20, determine the resonance frequency of acetone gas, acetone gas concentrations measured up to ppb level so as to obtain the linearity curve of the LPAS system and the lowest detection limit (BDT).

Laser photoacoustic spectrometer in Figure 1(a) operated at an electric current of 11,5 mA, voltage of 7,6 kV and a lock-in sensitivity of 100 mV. With a maximum gas pressure of ± 50 mbar obtained maximum laser power 4,5 W. Materials main gas that is used to turn on the laser gas helium (He), nitrogen (N_2) and carbon dioxide (CO_2). Acetone gas (C_3H_6O) detected at the laser line 10P20 with gas absorption coefficient of 10,8 atm^{-1} cm^{-1}. The output spectrum of the laser power shown in Figure 1(b).

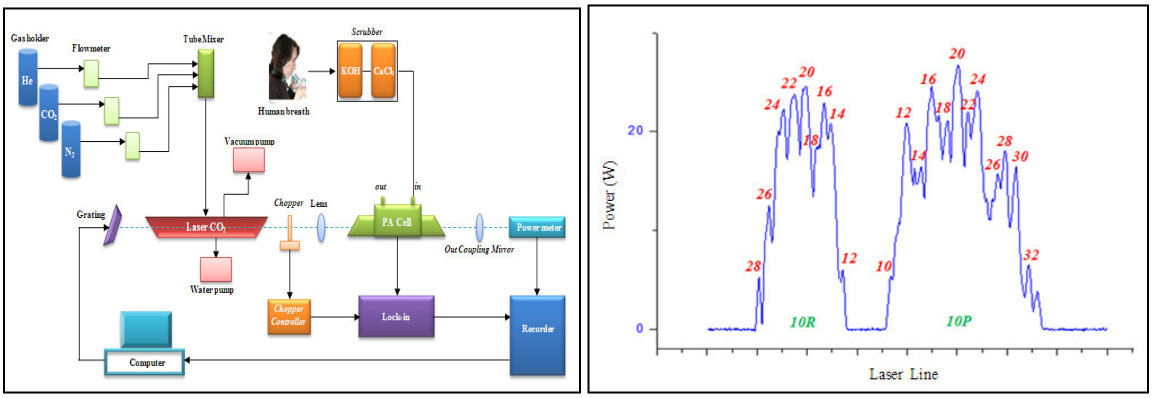

Figure 1. (a) Laser photoacoustic spectrometer, (b) The output spectrum of the laser power CO_2

The maximum resonance frequency curve is at 1640 Hz with normalized photoacoustic signal of 65,25 mV/W. To measure the background signal, the photoacoustic cell purged with nitrogen (N_2) and CO_2 laser irradiated. Signals derived not from gas uptake acetone but comes from heating the air on the windows and walls of the cell. Linearity laser photoacoustic spectrometer is determined based on the relationship of variations in gas concentration of acetone and normalized photoacoustic signal. Acetone gas concentration variation measured from 0,1 ppm to 10 ppm. The calculation of the linearity of the acetone gas will be used to determine the concentration of each sample while the lower limit of detection showed a sensitivity of laser photoacoustic spectrometer in detecting a gas tracing to the order of ppb.

Table 1. Characterictic of Laser Photoacoustic Spectrometers (LPAS) Intracavity

Characteristic	Value
Laser power CO_2	4,5 W
Gas absorption coefficient acetone	10,8 atm^{-1} cm^{-1}
Resonance curve	(1640 ± 5) Hz
Quality factor *Q*	(15,3 ± 0,7)
Background signal	(1,4 ± 0,1) μV/W
Noise	(0,160 ± 0,001) $\mu V/(Hz)^{1/2}$
Lower limit of detection	(2,3 ± 0,2) ppb

3. Detection of Acetone Gas Non-Invasive Based on Ages and Gender

After calibrating the LPAS instrument, we then do the detection of acetone gas through the human breath (non-invasive). The breath samples taken from 30 patients with diabetes mellitus and 30 healthy volunteers were assessed physically healthy and have never suffered from certain chronic diseases. Figure 2 shows the output spectrum of LPAS for acetone gas through the human breath. In part (a) shows the output spectrum acetone gas in one diabetic patient with a concentration of 612 ppb while in part (b) shows a healthy volunteer with a concentration of 44 ppb.

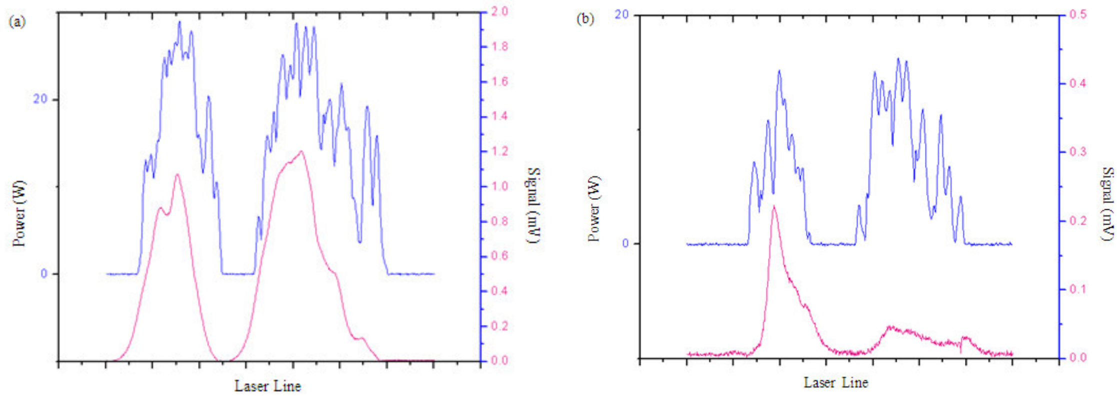

Figure 2. The output spectrum of LPAS for acetone gas through:
(a) patients with diabetes mellitus, (b) healthy volunteer

The pattern of acetone gas output spectrum for patients with diabetes mellitus is higher than the output spectrum pattern of healthy volunteers. This suggests that the LPAS instrument to function properly. Acetone

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gas detection results for 30 patients with diabetes mellitus have a concentration in the range of 367 ppb to 933 ppb with an average concentration of 624 ppb. The gas concentration of acetone to 30 healthy volunteers ranged from 44 ppb to 139 ppb with an average concentration of 85 ppb. Then analyzed the influence of age and gender of the gas concentration of acetone.

The correlation between the concentration of acetone gas on average for the gender is not significant. Acetone gas concentration average of 14 male patients amounted to 584 ppb with a correlation of $R^2 = 0{,}221$ and 16 female patients amounted to 660 ppb with a correlation value of $R^2 = 0{,}016$. This suggests that men and women have equal opportunities to be suffering from a certain chronic diseases, in this case diabetes mellitus.

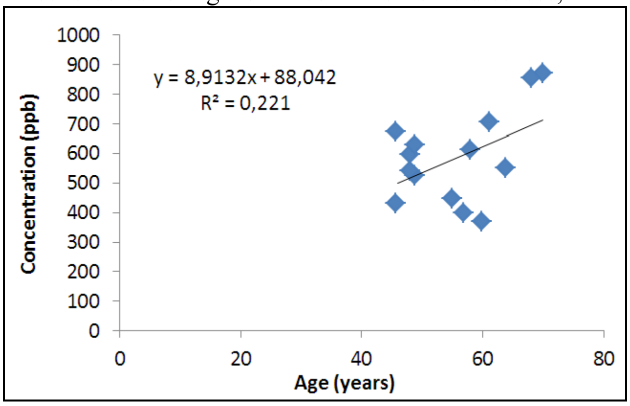

Figure 3. Graph correlation acetone concentration of 14 male patients

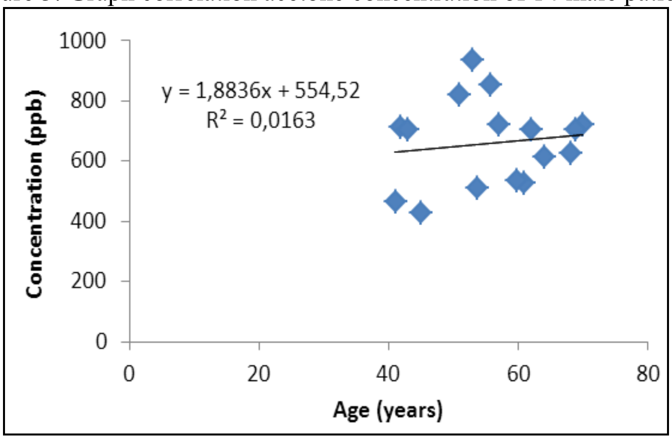

Figure 4. Graph correlation acetone concentration of 16 female patients

Table 2. The concentration of acetone by gender of the patients

Man			**Woman**		
Sample	**Age (years)**	**Concentration (ppb)**	**Sample**	**Age (years)**	**Concentration (ppb)**
1	46	426	1	41	466
2	46	672	2	42	711
3	48	591	3	43	705
4	48	542	4	45	429
5	49	522	5	51	813
6	49	628	6	53	933
7	55	444	7	54	507
8	57	396	8	56	855
9	58	613	9	57	719
10	60	367	10	60	530
11	61	705	11	61	527
12	64	545	12	62	702
13	68	853	13	64	612
14	70	872	14	68	625
			15	69	703
			16	70	723
n = 14	**Range**	**584**	**n = 16**	**Range**	**660**

In Figure 5 shows the correlation graph of acetone concentration based on the patient’s age. The results show that there is a correlation between the concentration of acetone on the patient's age at $R^2 = 0,7094$.

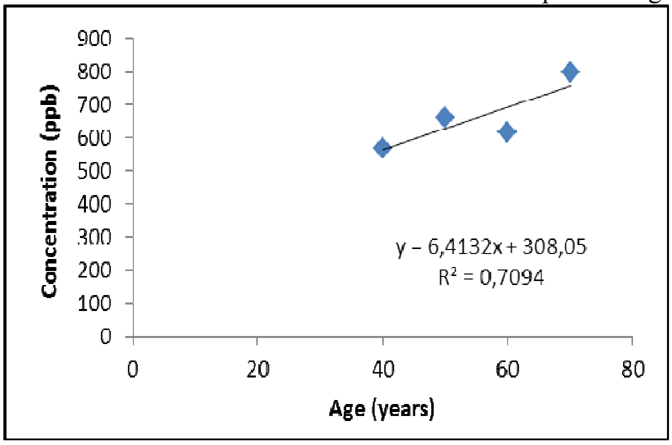

Figure 5. Graph correlation acetone concentration on the patient's age

Table 3. The concentration of acetone by age of the patients

Group of Age (years)	Concentration (ppb)	Sum (people)
40 – 49 tahun	569	10
50 – 59 tahun	660	8
60 – 69 tahun	617	10
> 70 tahun	797	2

If age increases, the concentration of acetone in the body will increase. This is because at the age of > 40 years, the human immune system decreases so prone to certain chronic diseases, in this case diabetes mellitus. The graph in Figure 6 shows almost no correlation between the concentration of acetone gas to the age or gender of healthy volunteers. The correlation of only $R^2 = 0,026$ and the concentration of acetone by an average of 85 ppb. This shows that the age below 30 years are still on average still have a good immune system and yet many suffer from chronic diseases.

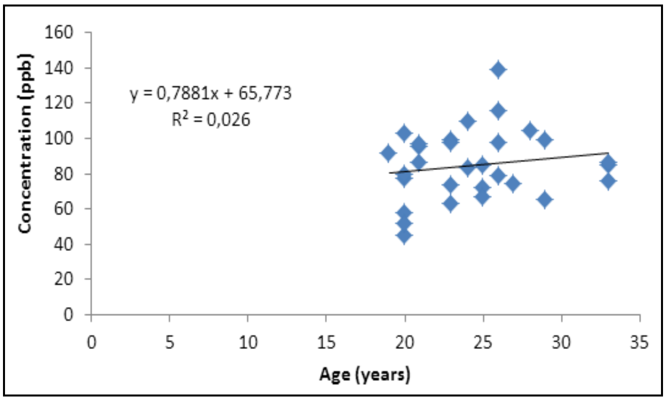

Figure 6. Correlation between the concentration of acetone gas to the age and gender of healthy volunteers

Qualitatively, the performance tool laser photoacoustic spectrometer to detect gas acetone as a biological marker of diabetes mellitus through human breath to the ppb level, accurate and has high sensitivity.

4. Conclusion

Based on the research results obtained, then the conclusion can be drawn:

1. Laser photoacoustic spectrometer operated at a maximum of 4.5 W of laser power and has a lower limit of detection (BDT) of (2.3 ± 0.2) ppb.
2. The concentration of acetone gas on average for 30 patients with diabetes mellitus are at 624 ppb, whereas the concentration of acetone gas averaged 30 healthy volunteers is as high as 85 ppb. The correlation between the concentration of acetone to gender is not significant. Acetone gas concentration average of 14 male patients amounted to 584 ppb with a correlation of $R^2 = 0,221$ and 16 female patients amounted to 660 ppb with a correlation value of $R^2 = 0,016$ while the correlation of the concentration of acetone on the patient's age is significant in the amount of $R^2 = 0,7094$. If age increases, the concentration of acetone in the body will increase. For healthy volunteers, almost no correlation between the concentration of acetone gas

to the age or gender of healthy volunteers.

References

Alan, G.G., and Hei Sook Sul., (2000), "Lipid metabolism-Synthesis and Oxidation", *Biochemical and Physiological Aspect of Human Nutrition,* Saunders, P. 330-5.

Cernat, R., Matei, C., Bratu, A.M., Popa, C., Dutu, D.C.A., Patachia, M., Petrus, M., Banita, S., and Dumitras, D.C., (2010), "Laser Photoacoustic Spectroscopy Method for Measurements of Trace Gas Concentration for Human Breath", *Rumanian Reports in Physics,* Vol. 62, No. 3. P. 610-616.

Mitrayana., (2008), "Rancang Bangun Spektrometer Fotoakustik dan Spektrometer Modulasi Panjang Gelombang Laser. Kajian Deteksi Gas *Biomarker* C_2H_4, C_3H_6O, NH_3, NO_2 dan NO dalam bidang Kedokteran", *Disertasi*, Universitas Gadjah Mada, Yogyakarta.

Tjokroprawiro, A., (2002), "Metformin: Molecular Basic For Clinical Appraisal Obesity and Insulin Resistance", *National Obesity Symposium I 2002,* Surabaya.

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